

N O T I C E

THIS DOCUMENT HAS BEEN REPRODUCED FROM
MICROFICHE. ALTHOUGH IT IS RECOGNIZED THAT
CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED
IN THE INTEREST OF MAKING AVAILABLE AS MUCH
INFORMATION AS POSSIBLE

METHOD AND RESULTS OF INTERPRETING GRADUATED
MEASUREMENTS OF WIDE GAP SPARK CHAMBERS

V. V. Akimov, G. V. Veselova, V. D. Kozlov

Translation of "Metodika i Rezul'taty Obrabotki Graduirovo-
chnykh Izmeriniy Shirokozazornykh Iskrovyky Kamer," Academy
of Sciences USSR, Institute of Space Research, Moscow,
Report Pr-406, 1978, pp. 1-26.

(NASA-TM-76244) METHOD AND RESULTS OF
INTERPRETING GRADUATED MEASUREMENTS OF WIDE
GAP SPARK CHAMBERS (National Aeronautics and
Space Administration) 27 p HC A03/HF A01

N81-13327

Unclas
CSCL 14B G3/35 29449



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. OCTOBER 1980

STANDARD TITLE PAGE

1. Report No. NASA TM- 76244		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Method and Results of Processing Graduated Measurements of Wide Gap Spark Chambers				5. Research Date October, 1980	
				6. Performing Organization Code	
7. Author(s) V.V. Akimov, G.V. Veselova, V.D. Kozlov Academy of Sciences of the USSR Institute of Space Research				8. Performing Organization Report No.	
				10. Work Unit No.	
9. Performing Organization Name and Address Leo Kanner Associates, Redwood City, California, 97063				11. Contract or Grant No. NASW-3199	
				13. Type of Report and Period Covered Translation	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration, Washington, D.C. 20546				14. Sponsoring Agency Code	
15. Supplementary Notes Translation of "Metodika i Rezul'taty Obrabotki Graduirovannykh Izmereniy Shirokozazornyykh Iskrovyky Kamer," Academy of Sciences USSR, Institute of Space Research, Moscow, Report Pr-406, 1978, pp. 1-26					
16. Abstract This article will describe the regimen of measuring gamma ray telescope plates using HP 9820 calculators. Results are presented that detail the graduated measurements of the angular resolution of wide gap spark chambers using photographic, video and vidicon information gathering schemes.					
17. Key Words (Selected by Author(s))				18. Distribution Statement Unlimited-Unclassified	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 25	22. Price

METHOD AND RESULTS OF INTERPRETING GRADUATED MEASUREMENTS OF WIDE GAP SPARK CHAMBERS

V. V. Akimov, G. V. Veselova, V. D. Kozlov
Academy of Sciences of the USSR, Institute of Space Research

One of the steps in setting up the experiment to record high en- /3*
ergy cosmic gamma rays using the "Gamma-I" gamma ray telescope was
calibration on the DESY accelerator (Hamburg, FRG); the basic element
of the instrument is a stack of wide-gap spark chambers [1].

The data obtained were processed independently by three groups:
the Moscow Engineering Physics Institute (MIFI [Moskovskiy inzhenerno-
fizicheskiy institut]), the Center for Nuclear Research in Sakle,
France, and the Institute of Space Research of the Soviet Academy of
Sciences (IKI AN SSSR [Institut kosmicheskikh issledovaniy, Adademiya
nauk, SSSR]).

In this work we shall describe the method, mathematical programs
and results of interpreting photographic data at IKI AN SSSR. These
data were obtained by irradiating the spark chambers with 100 MeV
gamma quanta and 2 GeV electrons with zero angles of incidence rela-
tive to the chamber assembly's axis.

We found that the angular resolution of spark chambers for 100
MeV gamma quanta comprise $\approx 1.8 \pm 0.1$ for both photographic projections.

Using a processing method which simulates throughout of informa-
tions from the spark chambers using a vidicon system, it was discovered
that with a digitization step correspondig to 0.5 mm in the scale of
the spark chambers, angular resolution of $1-2^\circ$ provided by the spark
chambers was not achieved.

I. The Gamma-I Instrument Calibration

*Numbers in the margin indicate pagination in the foreign text.

A number of Soviet and French institutions are working with the Gamma-I telescope in the field of gamma ray astronomy in volume energies/4 of $E_\gamma \geq 50$ MeV. The scientific goals of research with this instrument are [2]:

- measurement of spatial and energy characteristics of gamma radiation from the Galaxy;
- measurement of energy and time characteristics of gamma radiation from known, local sources;
- detection and investigation of local sources of gamma radiation as yet undiscovered.

The gamma ray telescope consists of scintillator and Cherenkov counters intended for the isolation of cases of quanta registration, measurement of their energy, and a rough (within the boundaries of a cone with a 15° open angle) determination of the direction of their arrival.

One of the primary elements of the gamma-ray telescope is the spark chambers, which provide additional identification of the recorded particles and which determine with greater precision the direction of arrival of gamma quanta. They also measure the energy of gamma-quanta at ≤ 200 MeV. To solve these tasks, it is necessary to fix the direction of motion of the electron and positron after creation of the pair, and to evaluate the energy of each of these particles.

The energies of the particles are measured according to their repeated scattering in the chamber electrodes. Therefore, a sufficiently large number of gaps is required, separated by layers of a medium in which the repeated scattering exceeds the indeterminacy in measuring the directions of particle motion. In addition, the conversion probability, and therefore the effectiveness of the instrument in recording gamma quanta, depend on the total thickness of the converter's layers. These considerations, taken with certain technical limitations imposed by the number of spark gaps (limitations of volume,

weight, power, flow of information, etc. in measurements taken on an artificial Earth satellite (AES) or high-altitude balloon), force one to use a converter .02 -- .04 thick with radiation length at 10 -- 15 spark gaps. On the other hand, large thickness of the converters decreases precision in determining the direction of motion of the constituent pair, inasmuch as electrons and positrons with energies of several tens of MeV are already significantly scattered even in the layer of medium between their point of origin and the first spark interval, and deviate even more strongly from the initial direction of motion in the subsequent intervals. /5

In choosing the design of spark chambers, therefore, we must optimize the thickness of the electrodes so that a satisfactory angular resolution is achieved at a sufficiently high conversion efficiency. The ratio $\Delta\alpha/\sqrt{E}$ may serve as the criterion (where $\Delta\alpha$ -- is the standard deviation in determining the direction of gamma quanta in any projection, and E is the effectiveness of detecting gamma quanta) since the probability of isolating the point source from the background is proportional to this magnitude.

The primary purpose in developing the Gamma-I system was to obtain an angular resolution that exceeded 2° with, at gamma-quanta energies of 100 MeV, a conversion probability of no less than 0.25, in order to have better characteristics than those of the instrument aboard the American satellite SAS-P ($\Delta\alpha \approx 4^\circ$) [3], and those the instrument mounted on the European satellite COS-B have ($\Delta\alpha \approx 5^\circ$) [4].

Preliminary analyses showed that this problem can be solved by using a stack of 12 wide-gap spark chambers (width of the gap 3 cm) with an optical information gathering system, and converter depths of 0.02 to 0.04 of the radiation length. Such chambers have an advantage over the narrow gap chambers used aboard the SAS-P and COS-B satellites in that the particle's direction of motion may be determined within each gap, since the spark follows the particle's trajectory (in narrow gap chambers sampling is done perpendicular to the electrodes). The stack of spark chambers with gap 3 cm was developed at MIFI. The /6

thickness of the aluminum converters alternates between 2 and 4 mm. At the Center for Nuclear Research in Sakle, similar chambers were constructed with converters made of molybdenum and tantalum 0.02 mm and 0.06 mm thick, respectively. The impulse voltage generators and the triggering system for the spark chambers were designed and constructed at MIFI.

The methods of information throughput from the spark chambers were provided for during the development of the Gamma-I instrument: photographic and video (vidicon). Observation of the spark chambers occurs from two mutually perpendicular directions. Images of the gaps are conveyed to the objective lens of the photo and vidicon systems using flat mirrors. To assure the spatial "compatibility" from both sides of each gap, an illuminated cross hair is placed on the assembled support of the chamber. A modified RFK-5 photorecorder does the photography.

To determine the angular resolution of the Soviet and French spark chambers, models of the apparatuses were graduated with a beam of electrons and "labeled" gamma quanta from the DESY accelerator (Hamburg, FRG). The chambers were calibrated in a beam of "labeled" photons with energies (energy of the photons changed) from 50 - 1 GeV and electrons with energies from 50 MeV to 2 GeV. The operation of the spark chambers was checked for differing masters of event selection and for the rotation angles of the instruments axis relative to the beam, equal to 0° and 18.6° .

The purpose of this direct interpretation was to obtain the operating characteristics of the spark chambers with energy of the gamma-quanta equal to 100 MeV.

II. Processing of Measurement Results at IKI AN SSSR

The following processing method was selected:

Stage 1. Inspection of the photographic film, classification and selection of photographs for further processing.

Stage 2. Printing of the selected photographs.

/1

Stage 3. Input of the coordinates for the sparks and reference labels into a computer.

Stage 4. Processing of the input information using a computer, and obtaining the physical characteristics of the instrument.

III. Inspection and Selection of Photographs for Subsequent Processing

On the film are photographs obtained during irradiation by gamma-quanta with energy 100 MeV and electrons with energy 2 GeV of the stack of spark chambers containing seven chambers with aluminum electrodes manufactured in the Soviet Union (with 1 to 7 gaps), and five French-made chambers with tantalum electrodes (8 to 12 gaps). Thickness of the electrodes: 4 mm of aluminum in front of gaps 1, 3, 5 and 7; 2 mm of aluminum in front of gaps 2, 4, and 6; 1 mm of aluminum and 0.06 mm of tantalum in front of gap 8 and 0.06 mm of tantalum in front of gaps 9, 10, 11 and 12.

Two projections of an event are simultaneously observed on the scanning BPO-1 apparatuses. Events were classified into five types during inspection:

"A" - two trajectories are visible with a common origin in one of the spark chamber electrodes, a "fork;"

"O" - a single track;

"N" - an uninterpreted event, usually consisting of several independent spark-overs;

"D" - two tracks are visible without a common origin; with the limits of the stack of spark chambers;

"S" - a complex event containing more than two tracks.

The frame numbers for the two projections of the event (from two films) are recorded in the logbook along with the type of event and the numbers of the gaps in which each trajectory begins and ends. Also recorded in the log are the gap numbers of the beginning and end of the δ -electron tracks. The operator in the "Notation" of the graph records /8 any peculiarities for the photograph (for example, the locations of spark-overs and false tracks, and breaks in numbering the frames, etc.).

Of the 900 events recorded as the spark chambers were exposed to 100 MeV gamma-quanta, 505 were selected in which a clear electron-positron pair (a "A" event) was observed.

From "A" type events, those that showed a conversion in front of the gaps 2, 3, 4 and 5 were chosen for further interpretation.

Additionally, type "O" events with a trajectory originating in front of gaps 2-5 were processed.

Of the events recorded as the chambers were irradiated with 2 GeV electrons, 21 were chosen for further processing.

IV. Printing the Photographs

The photographs were printed on 30 X 40 cm² contrast photographic paper.

In choosing this material, we were guided by the following considerations:

- 1). in contrast to photographic film of this size, particle tracks with low brightness appeared with greater contrast and could be more reliably processed ;
- 2). distortions caused by deformation of the photographic paper were within permissible limits according to experimental testing;
- 3). the mass production of a fairly large number of photographs

(several hundred) was less laborious on photographic paper than on film.

Testing for optical distortion introduced by the "dokumator" type enlarger showed distortion to be insignificant even at the periphery of the plate.

/9

The enlargement range equalled ≈ 20 frames, since large format photography entails some difficulty when operating a digitizer (see below).

The photograph number from the film of a given projection is recorded on each photograph, and the number of the negative containing the same event from another projection is written in parentheses.

To aid the operator of the digitizer, identifications of the particles and the trajectory belonging to the first or second particle are made after preparing the photograph.

An example of an event in two projections is presented in Figure 1. We see in this picture, in addition to the particle trajectories, the reference cross hairs which were mounted on the stand of the chambers. "Attached" to the cross hair coordinates is the system of photograph coordinates, relative to which the particle trajectory angles will later be measured.

V. Programming of Data and the Computer Processing of Photo Plates

The data was processed on HP 9820 calculators equipped with a peripheral device for input of graphic information (digitizer).

5.1 Basic Technical Characteristics of the HP 9820

The HP 9820 is a programmable desk top calculator. The programming language is algorithmic with elements from both Algol and Fortran.

Mode of operation: dialogue.

Time required for arithmetic operations: 20 μ s.

Memory: 480 registers.

The register has 10 decimal bits.

The calculator has an evolved system of peripheral apparatuses and is equipped with a library of standard programs. /10

5.2 Technical Characteristics of the Digitizer

The digitizer is a table with size of the working field for introducing information 62 X 62 cm². The table is equipped with a cursor. By operator signal, the coordinates of a point corresponding to the location of the cursor at a given moment are fed into the machine.

There are two modes of operation for the digitizer: the S mode and the C mode. The S mode is used for input of the coordinates of a single point, while the C mode is for input of a large quantity of data. In the latter mode the operator moves the cursor along the track as the corresponding point coordinates are fed into the machine with a frequency of 5 Hz. The input frequency may be decreased, having curtailed through programming the number of referrals to the digitizer. The digitization step of the digitizer is 0.25 mm on both the mutually perpendicular axes.

5.3 Cassette Magnetophone

The magnetophone is built into the computer. Magnetic tape is used for long-term information storage.

The magnetic tape is divided into files (zones). The size of the file must not exceed the machine's memory.

The capacity of recorded information using the HP firm's cassette and the graduation of magnetic tapes into files of 100 words constitutes $\approx 8 \times 10^3$ words.

5.4 Graphplotter

The system employs a two coordinate graphplotter that can accommodate graphics of up to 40 X 50 cm².

The resolution using standard HP flowmasters is 0.25 mm.

A detailed description of the HP 9820 and its peripheral devices is given in the firm prospectuses.

/11

5.5 General Organization of Programs for Processing

The memory of the machine is limited, and for this reason the processing program had to be broken down into several subprograms.

In total, 14 programs were written to realize the processing system.

All the programs were recorded on one magnetic "Program" tape.

The description of each program and calculation algorithms, and the structure of the data are given below.

2.6 Storage of Data on Magnetic Tape. Structure of the Data

The structure of the record was chosen so that the entire tape would not have to be inspected when seeking information on a given frame.

For this reason, the initial parts of the tape are reserved beneath the catalog. Recorded in the catalog are the numbers for the frame, projection, zone, and the initial information cell in the zone.

Included also into the catalog is reference information necessary for the interpretation of the photographs: the coordinates of the reference cross hair and the chamber electrodes, the levels of vidicon throughput and the most frequently used constants.

The size of the zone was chosen to be 120 words -- no larger to avoid complicating the exchange with the machine memory, and no smaller to curtail the number of referrals to the tape.

To conserve space on the tape, the entries were made without intervening pauses.

All of the information introduced into the system was stored in as compact a form as was possible. For example, by converting sparks into a single ten-bit word, one may store the X and Y coordinates of ten points! This is possible since the magnetic tape preserves not the coordinates of points in the track, but only those of the initially introduced point and the X and Y deviations relative to the preceding point. It is additionally required that $0 < \Delta X \leq 2$ and $|\Delta Y| \leq 1$ in units of the digitizer. In this way the coordinates of all the points on the track may be reproduced. /12

5.7 Order and Sequence of Interpretation

The input of spark coordinates is accomplished after the photographs of the tracks are prepared. To reduce errors in determining the angle of particle motion relative to the reference cross hairs and when simulating a vidicon throughput of information (see below), all the points on the tracks are programmed within the accuracy of the digitizer's step of digitization. It is desirable, although not obligatory, to put in two projections of one event, one after the other. This accelerates the calculation of the subsequent programs since the time required to rewind the magnetic tape has been reduced.

This program does not relate the coordinates of the track with the number of spark interval, although this information is needed (each gap has its own optical distortions). The number of the gap to which the photographed information points belong was determined according to the known coordinates of the first point on the track in the chamber and those of the chamber electrodes (the "Gap" program). An example of this program is presented in Figure 1.

After determining the gap number for each trajectory, a transition is made from track coordinates to the angle. The coordinates of the track are treated as a function of Y . $Y = A + Bx$. The coefficients A , B , ΔB and the intersection point of the track with the lines of the cross hairs are found by the least squares method. θ , $\Delta\theta$, δ (the angle, error and magnitude characterizing the intersection point of the track with the line of the cross hairs, respectively), are recorded on magnetic tape.

/13

We needed, for subsequent processing, only the values for the angles -- their errors and magnitudes that characterize the intersection point of the track with the line of cross hairs. Therefore it was expedient to operate with only these magnitudes.

To calculate the true angles of particle motion in a single projection, the angles in another projection must be known.

The "unification" program recorded onto tape for each particle (e^+ and e^-) the gap number, θ_x , $\Delta\theta_x$, δ_x , θ_y , $\Delta\theta_y$, δ_y . A significant compaction of information took place at this stage (about a ten fold reduction).

The images of the projected angles of particle movement (θ_x , θ_y) are tied to the true angles ϕ_x and ϕ_y by the equations

$$\left. \begin{aligned} \tan \phi_x &= \frac{(A_1x + A_2x\delta_x) \tan \theta_x + (A_3x + A_4x\delta_x) \tan \theta_y + A_5x + A_6x\delta_x}{1 + A_7x \tan \theta_y} \\ \tan \phi_y &= \frac{(A_1y + A_2y\delta_y) \tan \theta_x + (A_3y + A_4y\delta_y) \tan \theta_y + A_5y + A_6y\delta_y}{1 + A_7y \tan \theta_x} \end{aligned} \right\} \quad (1)$$

where δ_x , δ_y are magnitudes connected with the coordinates of the cross hair and spark by $\delta = \frac{C_1}{C_1 + C_2} = \frac{C_2}{C_1 + C_2}$.

C_1 and C_2 are the distances from the intersection point of the trajectory and cross hairs to the left and right of the reference cross hairs, respectively;

$\Delta\alpha_x$ and Δy are the angles between the line joining the cross hair and the line parallel to the electrodes.

To determine all the constants A_{ix} and A_{iy} entering into the formula, we used photographs of the world oriented differently from the coordinate planes of the instrument. By means of these photographs we measured the angles θ_{ix} and θ_{iy} , for which the true projection angles ϕ_{ix} and ϕ_{iy} are known. 75 values for the angles θ_{ix} and θ_{iy} were measured for each gap, and all the constants of formula (1) were found by the least squares method. The calculation of the coefficients was done at MIFI. /14

The transfer from measured to true angles according to formula (1) was accomplished with the "Mira" program. Results of the calculation were transcribed onto the magnetic tape of secondary data.

To check the information obtained after the transfer to true angles, the printout of the magnetic tape was made on the "Print" program. To interpret electron and "single" gamma quanta events, this program occurred last.

The directions of motion of the electron-positron pair were reproduced by three methods in order to obtain the angles ϕ_x and ϕ_y ;

1. The direction of d_1 and Δd_1 , the sparks in the first gap following pair creation, was used to find the direction of the track;

2. The direction of the track was defined as a weighted direction direction of all the sparks of a given track:

$$\alpha = \frac{\sum d_i w_i}{\sum w_i}; \quad w_i = \begin{cases} \frac{1}{\Delta \alpha_i} b_i \prod_{k=1}^{i-1} \text{int} (1 + b_k - b_{k+1}) & \text{for } i > 1 \\ \frac{1}{\Delta \alpha_i} & \text{for } i = 1 \end{cases}$$

$$b_i = \text{int} t^{-2} (1 + |\alpha_i - \alpha_1|)$$

(where the angles α_1 are expressed in degrees).

3. Analogous to Paragraph 2, but where $b_1 = \text{int} t^{-2} (1 + .5 [\alpha_1 - \alpha_1])$.

The standard deviation (δ) of the track's direction was also calculated by the second and third methods,

$$\delta = \sqrt{\frac{\sum W_i (\alpha_i - \alpha)^2}{(N-1) \sum W_i}}$$

where N is the number of tracks included in averaging the sparks.

/15

The direction of the gamma quanta was found as the weighted average of the track directions of the electron and positron with weights equal to A/δ^2 , where

$$A = \begin{cases} 0 & K \leq 2 \\ \frac{K-1}{\sqrt{\sum_{i=1}^K V_i \theta_{i,i-1}^2}} & K > 2 \end{cases}$$

(and K is the number of sparks on a track);

$\theta_{i,i-1}$ is the spatial angle between the directions of sparks in the $i-1$ gaps;

V_i is the weight inversely proportional to the thicknesses of the medium between the gaps.

The three variants of the calculation described were realized with the "Direction" program. The results were transcribed onto magnetic tape of secondary processing and printed in the form of tables.

VI. Results of Processing

6.1 Results of Processing Events Induced by Electrons with Energy 2 GeV

Twenty-one events of recording electrons with energy 2 GeV were processed to determine the contribution to angular resolution of distortions and inaccuracy in tracking sparks by particle tracks.

Figure 2 illustrates the deviation distributions of spark directions from the average, which is determined for 7 gaps.

The angular resolution obtained of $\approx 1^\circ$ can be considered optimum

for this processing method.

6.2 Results of Processing Events Induced by Gamma Quanta with Energy 100 MeV

All three of the methods described above for establishing gamma quanta motion gave identical results within limits of experimental error.

/16

Figure 3 consists of histograms of the gamma quanta directions for all three variants of the calculations in two projections.

The standard deviations for these distributions constitute 1.9, 2.1, and 2.0° for the X-projection, and 2.3, 2.3 [sic. 2.2] and 2.1 for the Y-projection. However, these distributions are not purely Gaussian, and a more correct and characteristic distribution width would be the half-width of the region, to the left and right of which about 1/6 of all the events lie. These values of $1/2 \Delta 2/3$ in the distributions presented constitute $\approx 1.6^\circ$ for the X-projection and $\approx 1.8^\circ$ for the Y-projection. The boundaries to the left and right of which about 1/6 of all events lie are indicated with arrows in Figure 3. The error in determining these values comprised $\pm 0.1^\circ$ for all variations.

The conclusion can be made from these results, that angular resolution was better than 2° when recording gamma quanta with energy 100 MeV, inasmuch as the deviations obtained were amplified by:

- a) divergency in the gamma-quanta beam;
- b) the spread of recorded gamma quanta was $\approx 40\%$;
- c) processing errors.

6.3 Simulation of Vidicon Throughput of Information

It was assumed that the gaps would be observed at three levels

with vidicon systems, and the step of relative digitization of the coordinate along the gap would constitute $\approx 10^{-3}$ or about 0.5 mm in the initial scale. The digitizer has the same digitization step if one considers that the image on the photograph is half its actual size. This allows a simulation vidicon information throughput to be used, if of all the sets of points describing the spark, the ones nearest to the given levels of vidicon information scanning are chosen.

Several variants of vidicon information throughput were simulated: /17/

1. At three levels: 0.25, 0.5 and 0.75 of the gap width;
2. At three levels: 0.375, 0.5, and 0.625 of the gap width;
3. At five levels: 0.25, 0.375, 0.5, 0.625, and 0.750 of the gap width.

The levels are given by five constants listed in the reference data catalogs of the magnetic tapes. This allowed the variants of the vidicon throughput to be easily altered without changing the program.

Several special programs were written for simulation of the vidicon system. The "Vidicon" program selected from all sets of points the five points nearest points at the prescribed given level. The coordinates of the selected points were stored in a compact form on magnetic tape.

The "Vidicon Graph" program was used for testing operation of the "Vidicon" program and also informed the operator how often the directions of motion would have to be established by three and five points. It graphs the cross hair coordinates, the position of the chambers' electrodes and the coordinates of the points selected.

The direction of each spark is determined according to the coordinates of the chosen points. The "Vidicon Approximations" program was used for this.

After recalculation of the coordinates at the angle of motion of the particles, the magnetic tapes underwent secondary processing. This was done according to the "Unification vidicon" program. The problems solved by this program are similar to those solved by the "Unification" program.

In contrast to the "Unification" program, one must indicate the number of the vidicon variants in this program.

Thus we were able to transcribe the simulation of the vidicon throughput onto magnetic tape.

6.4 Results of Simulating Vidicon Information Throughput

Vidicon information throughput was simulated for type "A" events and for electrons with energies 2 GeV.

/18

The histograms corresponding to the direction distributions were plotted. The histograms for "A" events (for the three variants of calculating the gamma quanta directions in two projections) are presented in Figure 4.

A distinguishing characteristic of these distributions is the appearance of several narrow maximums (discreteness) in the distributions, caused (compare with Figure 3) by discreteness of the digitizer. One variant was simulated for gamma quanta: levels 0.25, 0.5 and 0.75.

The values $1/2\Delta^2/3$ constituted $\approx 2.7^\circ$ in this case for all the variants of calculation. The widening of the distributions as compared with Figure 3 was caused by digitization of values of the angles.

The most pronounced effect induced by digitization appeared when interpreting data of events produced by electrons with energy 2 GeV. Simulation with all 3 vidicon variants was used for electrons.

For a more precise explanation of this effect, digitization was constructed of spark direction distributions in electron events for

the X-projection, up to the point where corrections had to be introduced to compensate for optical distortions (see Figure 5).

The distance between peaks ΔB in the distributions may be explained by geometrical expressions:

$$\Delta B = \frac{d}{e} \text{ where } d \text{ is the unit of digitization;}$$

l is the distance between the vidicon's outer levels.

For $d = 0.5$ mm, $l = 15$ mm, $l_2 = 7.5$ mm, $\Delta B_1 = 1.9^\circ$ and $B_2 = 3.8^\circ$, respectively, i.e., ΔB is of the same order of magnitude as the angular resolution $\Delta\alpha$.

With five levels, a collection of peaks appears that corresponds to varying distances between levels.

/19

In order to provide the angular resolution achieved with photographic throughput of information, it is necessary that $n = \Delta\alpha/\Delta\beta$ exceed 3 ($\Delta\alpha$ is the angular resolution of the instrument).

With three levels present and $l \approx 15$ -- 18 mm, d must be approximately equal to 0.1 to 0.15. In this case, the angular resolution measured with the vidicon system coincides with the true value with a 95% probability.

VII. Method of Improving Angular Resolution

Besides the purely technical capability (improving the quality of operation of the spark chambers), one may improve the angular resolution by altering slightly the processing method. For example, an angular resolution of $1.4 \pm 0.1^\circ$ was obtained for events characterized by an angular separation of a pair $\leq 5^\circ$.

VIII. Conclusion

The data on the angular resolution of the spark chambers obtained

at the IKI AN USSR were verified by other groups of experimenters interpreting the calibration data (MIFI and the Center for Nuclear Research in France).

We state these results:

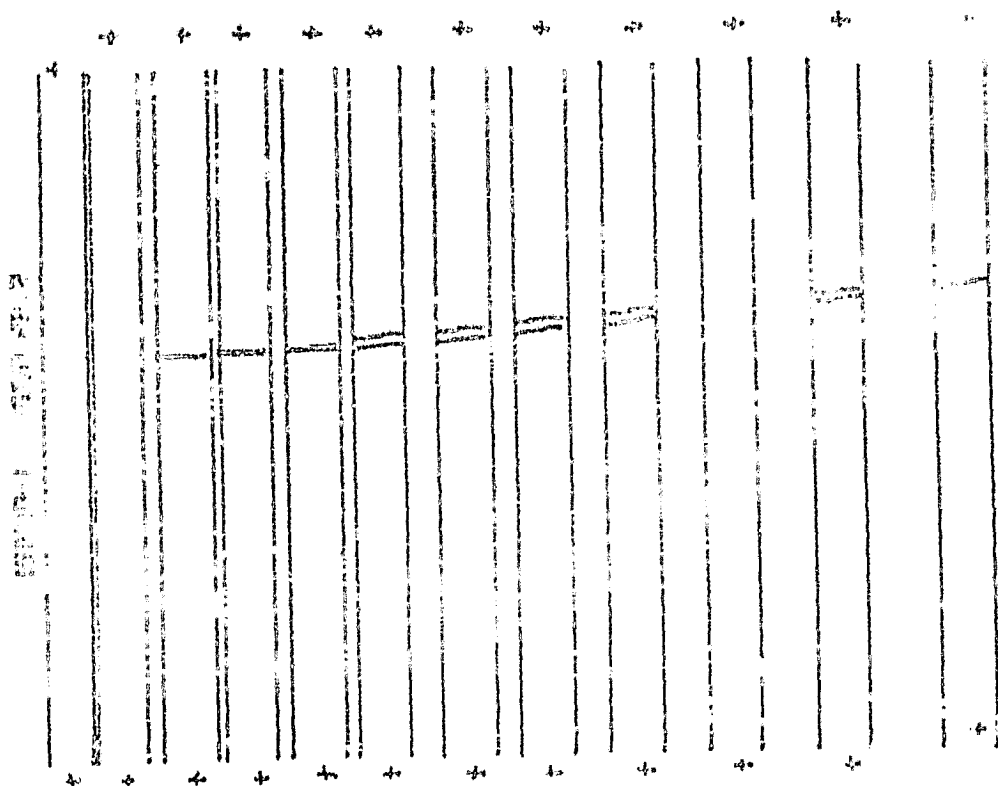
1. A method for processing data from wide gap spark chambers on an HP 9820 calculator was conceived and experimentally tested;
2. It was demonstrated that the angular resolution of the Gamma-I instrument is better than that of the SAS-P and COS-B devices;
3. It was also shown that altering the method of selecting events could improve the instruments' angular resolution;
4. A vidicon information throughput system was modeled and its optimum operating characteristics found. These characteristics were considered in developing a vidicon information throughput system.

REFERENCES

1. Akimov, V. et al., Nucl. Instr. and Method., 147, 329-332 (1977).
2. Akimov, V. et al., Proceedings 12th ESLAB Symposium Fraskati, 269-275, 1977.
3. Fichtel, C. E. et al., Astrophys. J., 198, 163-182 (1975).
4. Shucla, P. G. and H. A. Mayer-Hasselwander, Proceedings 9th ESLAB Symposium Fraskati, 339-344, 1974.

ANNOTATIONS TO DIAGRAMS

- Figure 1. Results on one event in two projections from the graph plotter.
- Figure 2. Distributions of deviations in the direction of sparks from the average direction of motion for electrons with energy 2 GeV.
- Figure 3. Distribution of the directions of 100 MeV gamma quanta for three variants of calculation and for two projections.
- Figure 4. Distribution of the directions of arrival of gamma quanta with energy 100 MeV for three variants of calculation and for two projections, simulating a vidicon throughput of information at three levels - 0.25, 0.5 and 0.75 of the gap width.
- Figure 5. Distribution of spark deviations from the average direction of motion of electrons with energy 2 GeV using three variants of the vidicon information throughput (X-projection).



ORIGINAL PAGE IS
OF POOR QUALITY

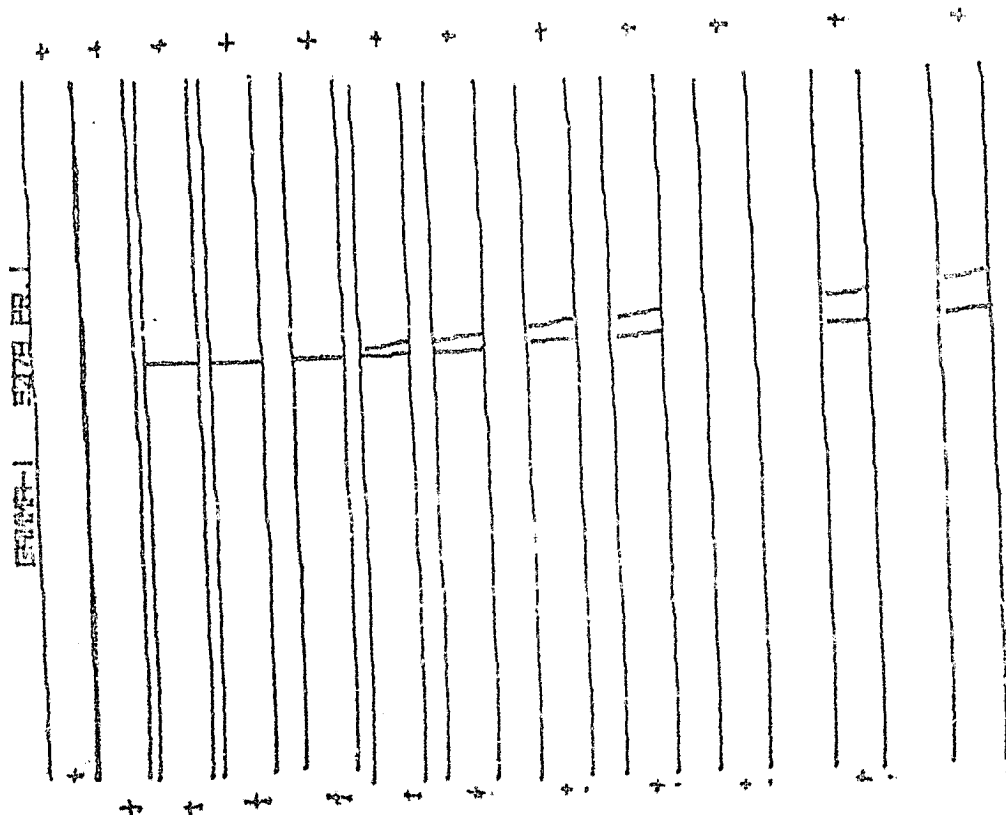


Figure 1

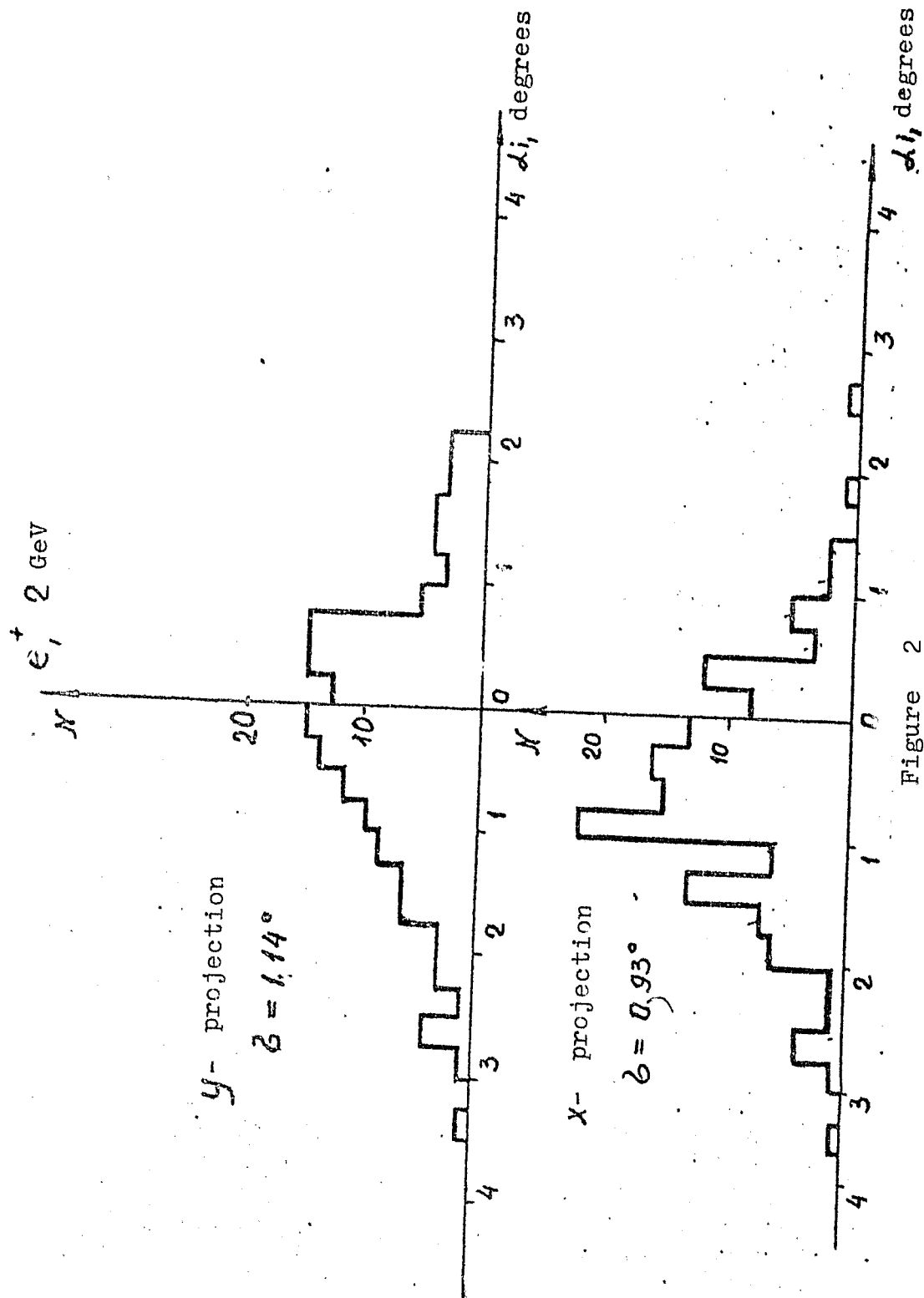


Figure 2

γ -quanta

$E = 100$ MeV

Quanta

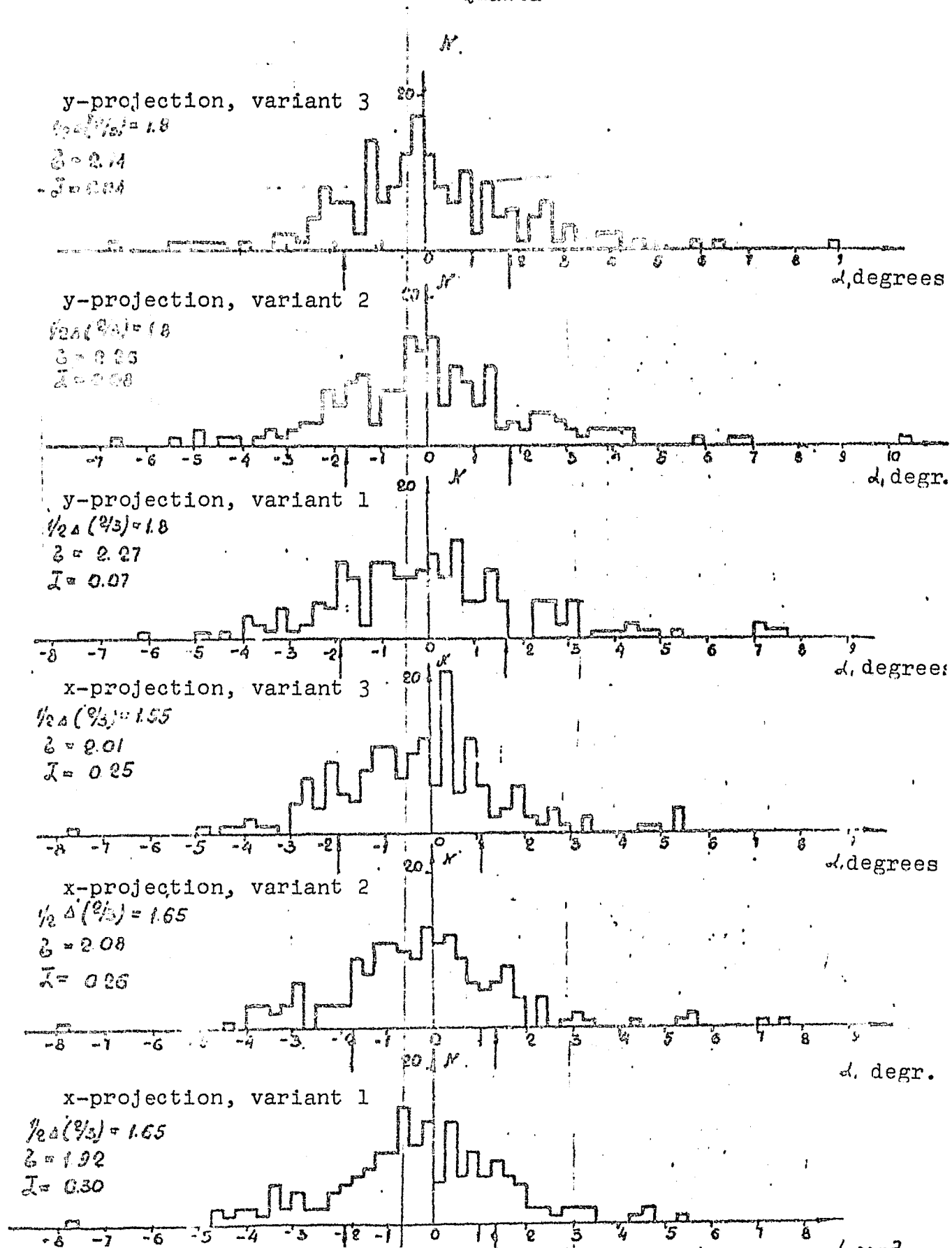
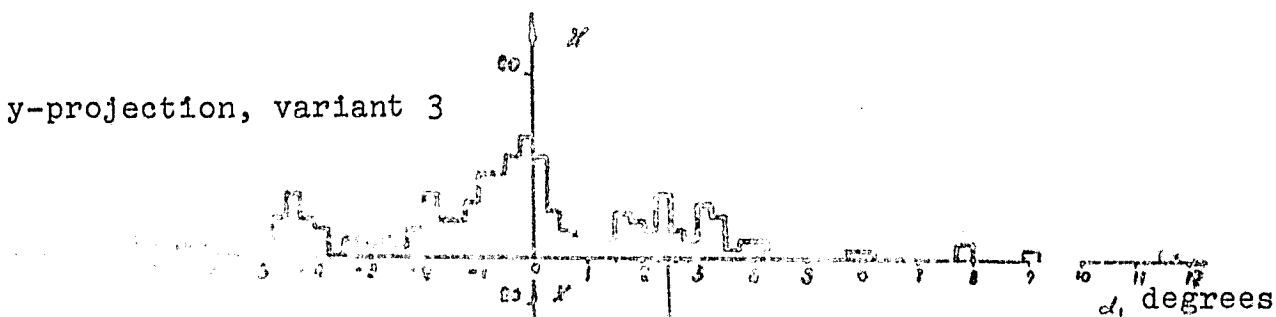


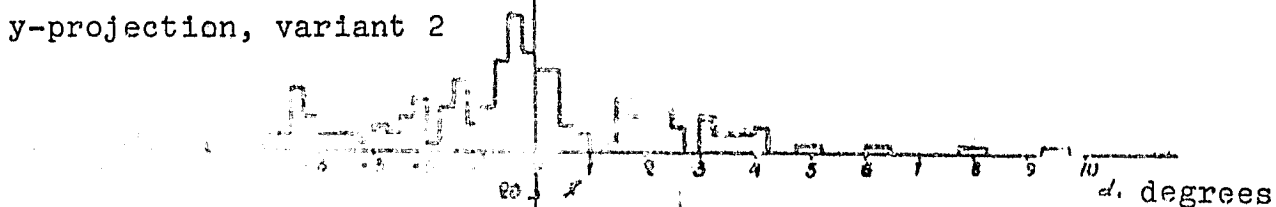
Figure 3

Y-Quanta, $E = 100 \text{ MeV}$

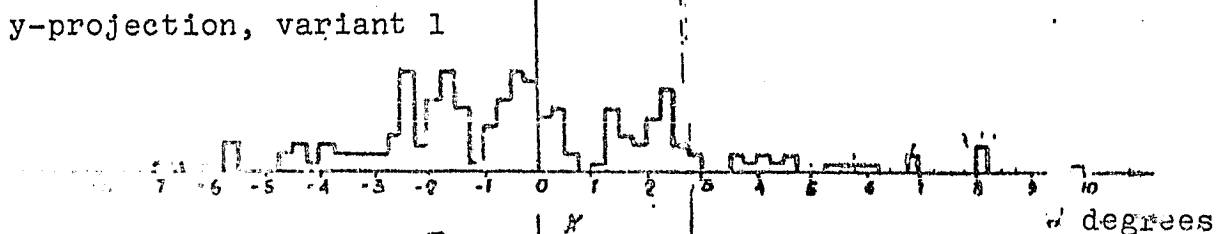
y-projection, variant 3



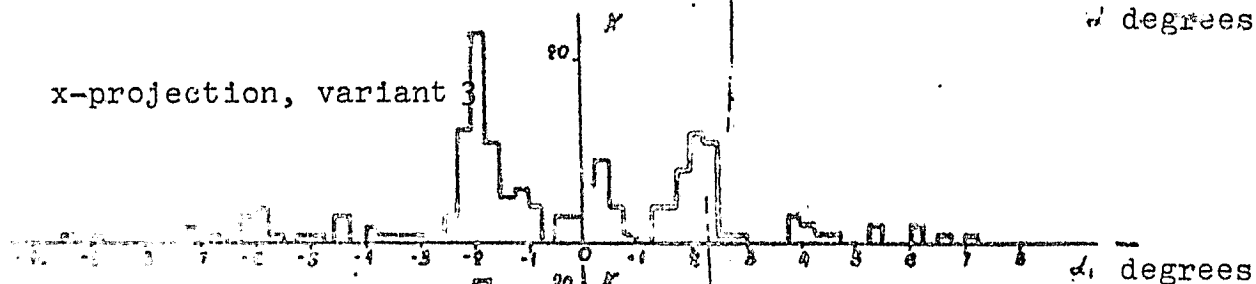
y-projection, variant 2



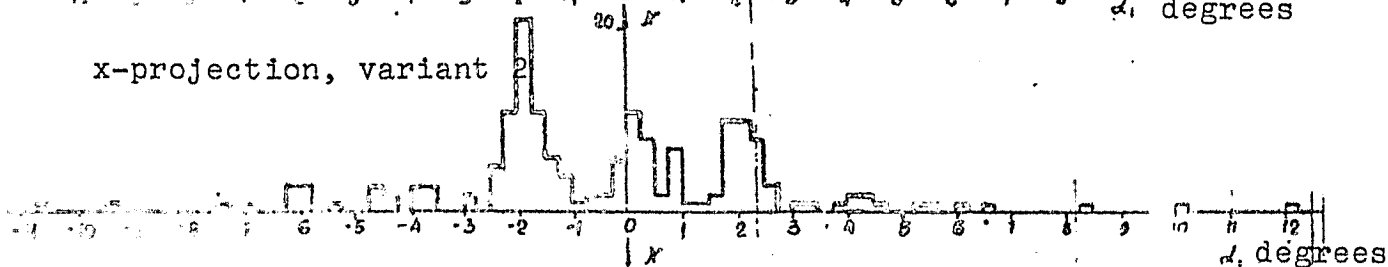
y-projection, variant 1



x-projection, variant 3



x-projection, variant 2



x-projection, variant 1

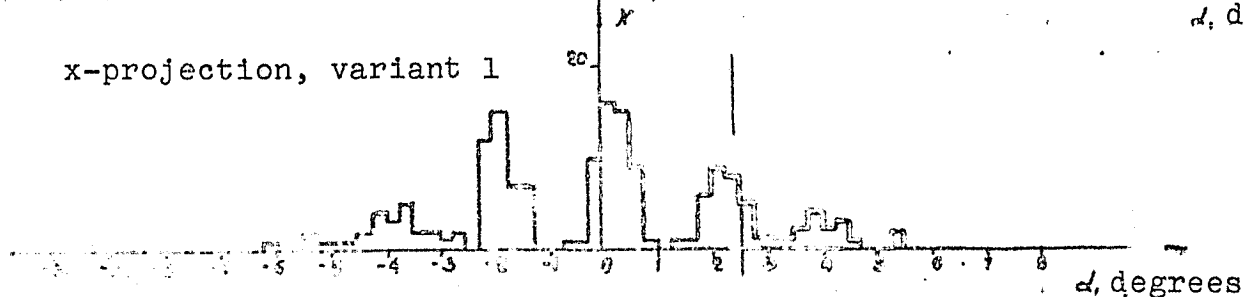
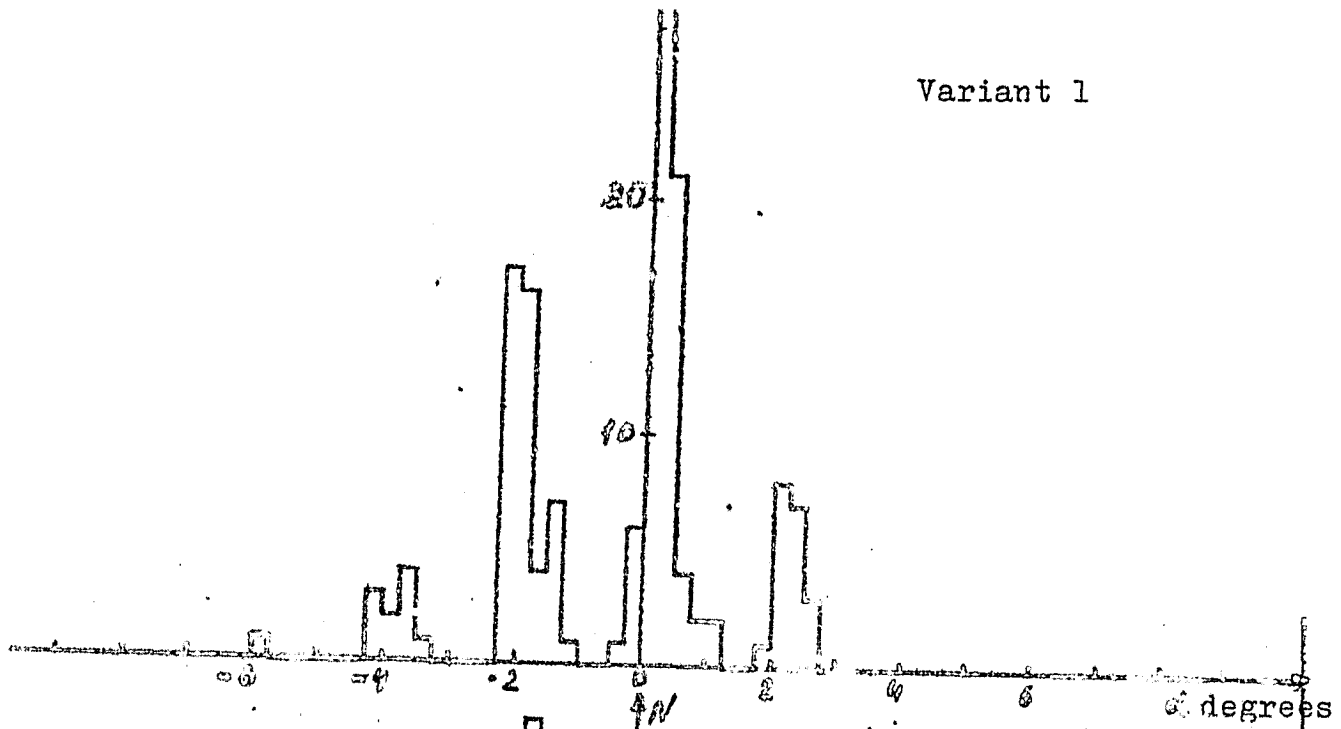


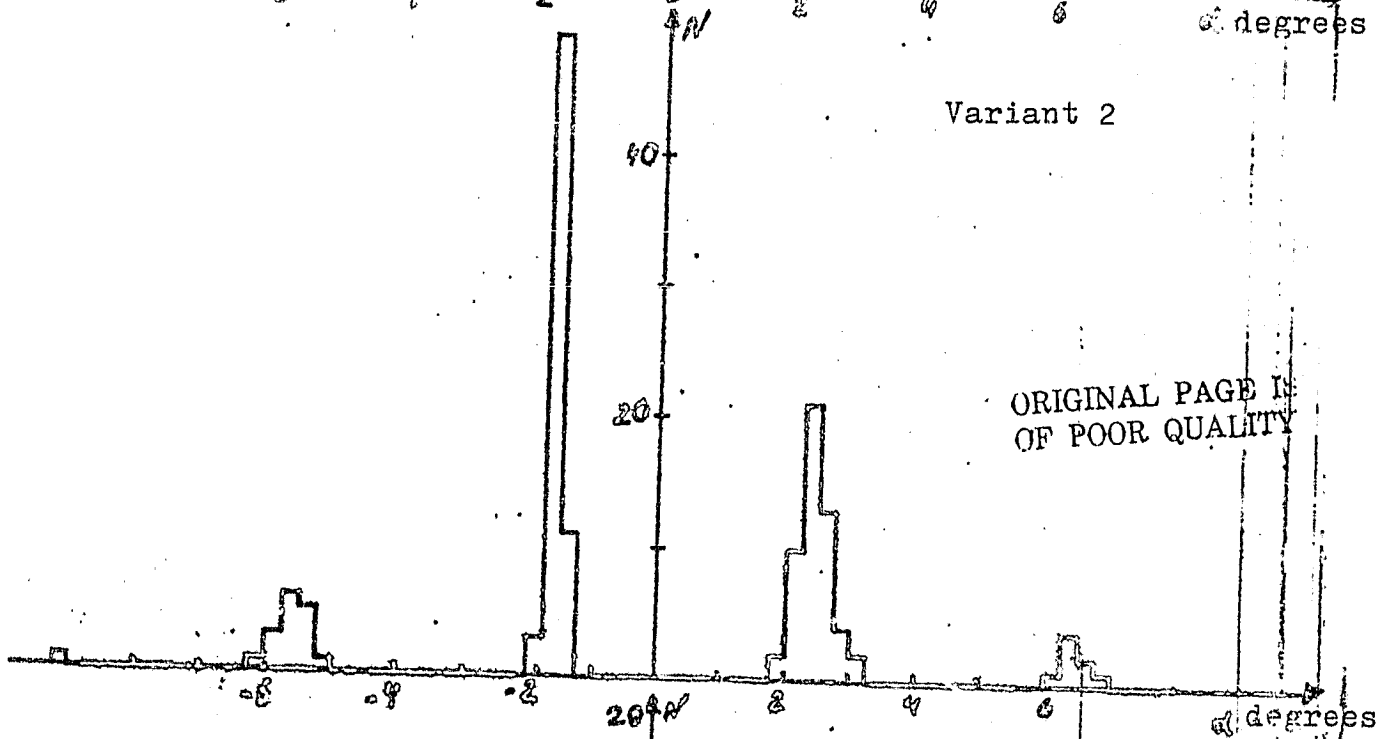
Figure 4

ORIGINAL PAGE IS
OF POOR QUALITY

Variant 1



Variant 2



ORIGINAL PAGE IS
OF POOR QUALITY

Variant 3

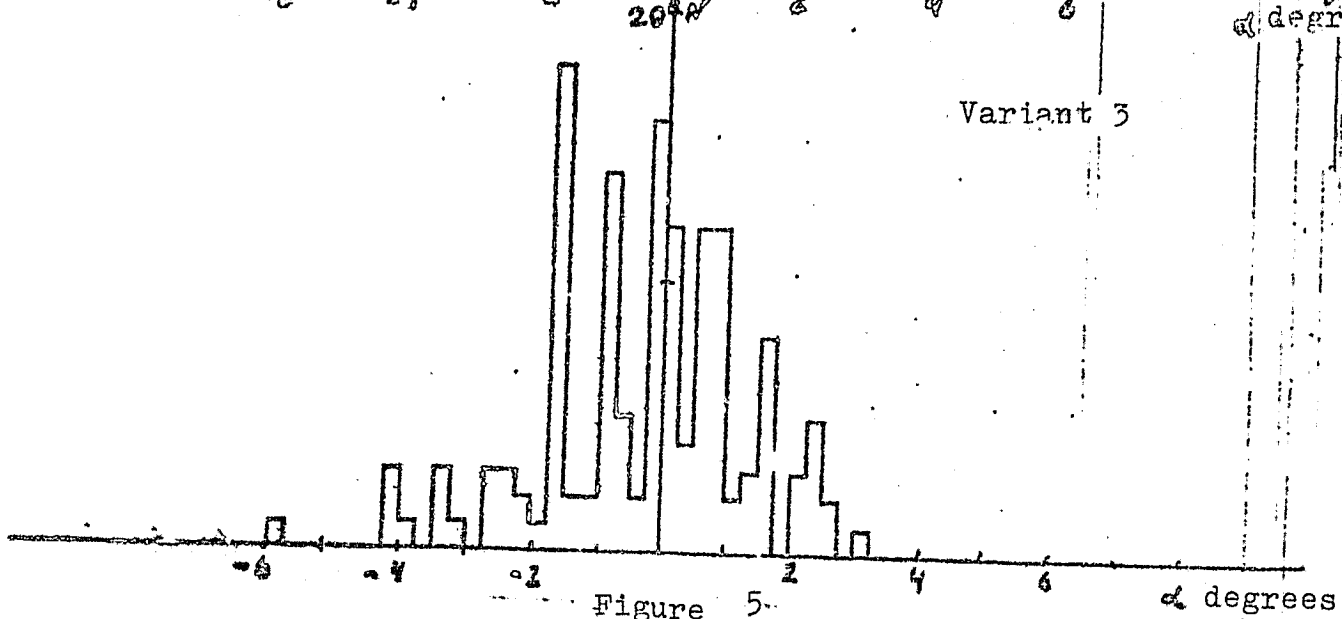


Figure 5